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# NGA STANDARDIZATION DOCUMENT

# Accuracy and Predicted Accuracy in the NSG: Glossary of Terms

## (2016-11-17)

## Version 1.0

# Forward

This handbook is approved for use by all Departments and Agencies of the Department of Defense.

Comments, suggestions, or questions on this document should be addressed to the GWG World Geodetic System (WGS) and Geomatics (WGSG) Focus Group, ATTN : Chair, WGS/Geomatics Standards Focus Group, ncgis-mail.nga.mil or to the National Geospatial-Intelligence Agency Office of Geomatics (SFN), Mail Stop L-41, 3838 Vogel Road, Arnold, MO 63010 or emailed to GandG@nga.mil.

# Summary of Changes and Modifications

| Revision | Date | Status | Description |
|---|---|---|---|
| **1.0** | 20161117 | FINAL | INITIAL PUBLICATION |
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# Contents

# 1 Scope

This Glossary of Terms supports the series of information and guidance documents titled, Accuracy and Predicted Accuracy in the National System for Geospatial Intelligence (NSG). This collection contains the following documents:

| | | |
|---|---|---|
| TGD 1 | Accuracy and Predicted Accuracy in the NSG: | Overview and Methodologies |
| TGD 2a | Accuracy and Predicted Accuracy in the NSG: | Predictive Statistics |
| TGD 2b | Accuracy and Predicted Accuracy in the NSG: | Sample Statistics |
| TGD 2c | Accuracy and Predicted Accuracy in the NSG: | Specification and Validation |
| TGD 2d | Accuracy and Predicted Accuracy in the NSG: | Estimators and Quality Control |
| TGD 2e | Accuracy and Predicted Accuracy in the NSG: | Monte-Carlo Simulation |
| TGD 2f | Accuracy and Predicted Accuracy in the NSG: | External Data and Quality Assessment |

All documents in the series, "Accuracy and Predicted Accuracy in the NSG", are intended to provide technical guidance to inform the development of geospatial data accuracy characterization for NSG GEOINT collectors, producers and consumers -- accuracy characterization as required to describe the trustworthiness of geolocations for defense and intelligence use and to support practices that acquire, generate, process, exploit, and provide geolocation data and information based on geolocation data. Today, both the sources and desired uses for geospatial data are quickly expanding. Throughout the NSG, trusted conveyance of geospatial accuracy is broadly required for a variety of traditional and evolving missions including those supported by manual, man-in-the-loop, and automated processes. This guidance is the foundation layer for a collection of common techniques, methods, and algorithms ensuring that geospatial data within the NSG can be clearly requested, delivered and evaluated as fit for desired purpose whether by decision makers, intelligence analysts, or as input to further processing techniques.

TGD 1, Overview and Methodologies, contains references to and is referenced by all of the other more detailed topical Technical Guidance Documents. These documents, TGD 2a – TGD 2f, also contain cross-references amongst themselves. All Technical Guidance Documents also reference external public as well as "NGA approved for public release" documents for further insight/details. While each individual document contains definitions for important relevant terms, this document, TGD 1-G, compiles all important terms and respective definitions of use particular to this series of documents to ensure continuity and provide ease of reference.

The TGD 2 documents are also considered somewhat top-level in that they are not directed at specific systems. They do provide general guidance, technical insight, and recommended algorithms. The relationship of the Technical Guidance Documents with specific GEOINT Standards documents and specific Program Requirements documents is presented in Figure 1-1, where arrows refer to references.

That is, in general, specific product requirement documents reference specific GEOINT standards documents which reference specific technical guidance documents.

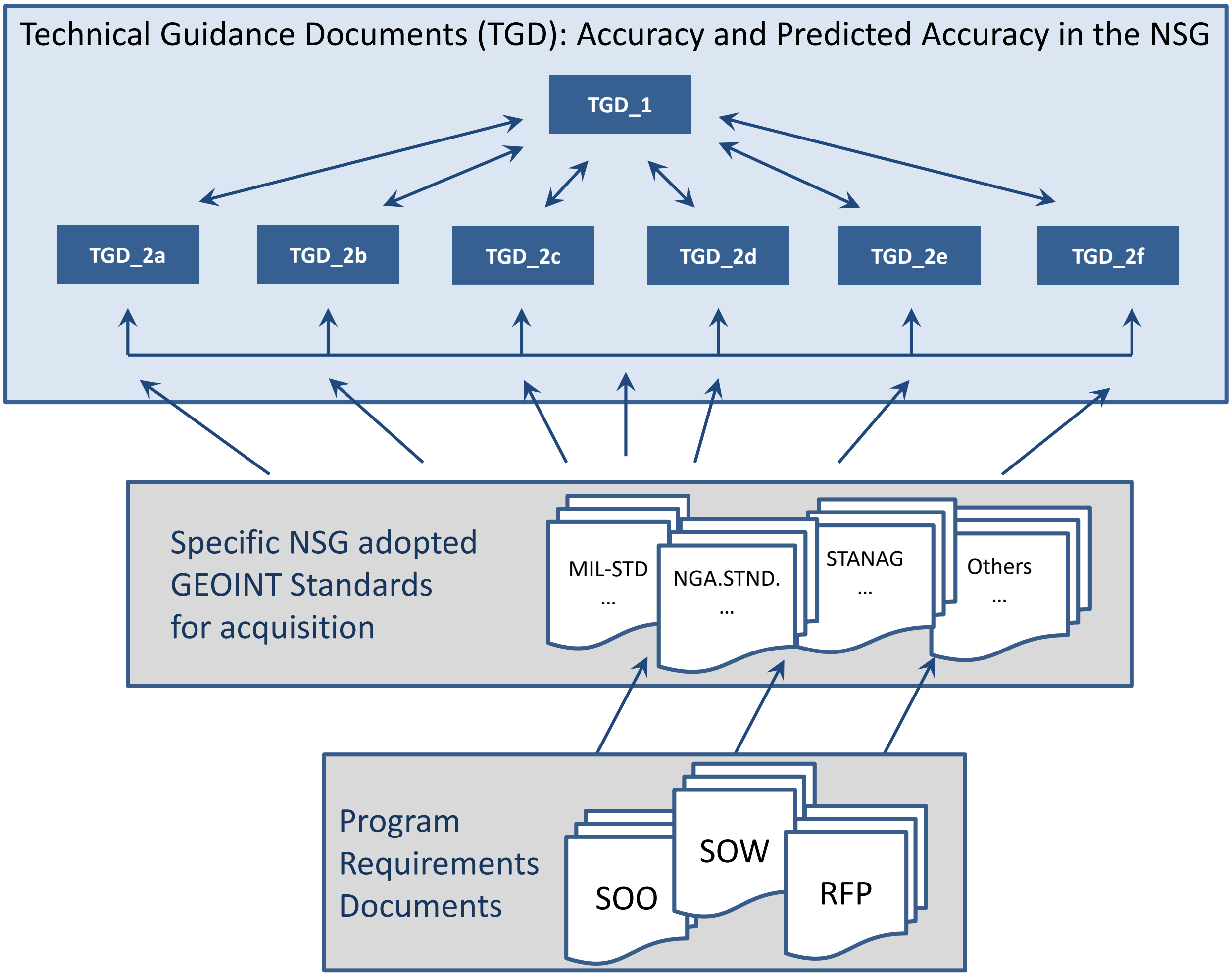


**Figure 1-1:** The relationships between the Technical Guidance Documents, GEOINT Standards Documents, and Program Requirement Documents

Accuracy and Predicted Accuracy in the NSG: Glossary of Terms, Technical Guidance Document (TGD) 1-G is for guidance only and cannot be cited as a requirement.

# 2 Applicable Documents

The documents listed below are not necessarily all of the documents referenced herein, but are those needed to understand the information provided by this information and guidance document.

## 2.1 Government specifications, standards, and handbooks

NGA.SIG.0026.01_1.0_ACCOVER, Accuracy and Predicted Accuracy in the NSG: Overview and Methodologies, Technical Guidance Document (TGD) 1

NGA.SIG.0026.03_1.0_ACCPRED, Accuracy and Predicted Accuracy in the NSG: Predictive Statistics, Technical Guidance Document (TGD) 2a

NGA.SIG.0026.04_1.0_ACCSAMP, Accuracy and Predicted Accuracy in the NSG: Sample Statistics, Technical Guidance Document (TGD) 2b

NGA.SIG.0026.05_1.0_ACCSPEC, Accuracy and Predicted Accuracy in the NSG: Specification and Validation, Technical Guidance Document (TGD) 2c

NGA.SIG.0026.06_1.0_ACCESQC, Accuracy and Predicted Accuracy in the NSG: Estimators and Quality Control, Technical Guidance Document (TGD) 2d

NGA.SIG.0026.07_1.0_ACCMTCO, Accuracy and Predicted Accuracy in the NSG: Monte-Carlo Simulation, Technical Guidance Document (TGD) 2e

NGA.SIG.0026.08_1.0_ACCXDQA, Accuracy and Predicted Accuracy in the NSG: External Data and Quality Assessment, Technical Guidance Document (TGD) 2f

# 3 Glossary of Terms

The following table contains significant and supporting terms used throughout the series of documents, *Accuracy and Predicted Accuracy in the NSG*. For each term there is also a mapping to the specific Technical Guidance Document/s it is referenced within – either in Section 3, *Definitions* or Appendix A, *Additional Terms and Definitions*. When relevant, reference/s to key informative sources are included.

| Technical Guidance Document (TGD) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 2a | | 2b | | 2c | | 2d | | 2e | | 2f | | | | |
| 3 | A | 3 | A | 3 | A | 3 | A | 3 | A | 3 | A | 3 | A | Term | Definition | Source/s |
| | x | | x | | x | | x | | | | x | | | ***A priori*** | Relating to or denoting reasoning or knowledge that proceeds from theoretical deduction rather than from observation or experience.<br>• For typical NSG accuracy and predicted accuracy applications, *a priori* refers to a mathematical statistical model of errors and/or the corresponding state vector containing those errors prior to its adjustment using additional information. | k |
| | x | | x | | x | | x | | | | x | | | ***A posteriori*** | Relating to or denoting reasoning or knowledge that proceeds from observations or experiences to the deduction of probable causes.<br>• For typical NSG accuracy and predicted accuracy applications, *a posteriori* refers to a refined mathematical statistical model of errors and/or the corresponding state vector containing those errors following its adjustment using additional information. | k |
| | x | | x | | x | | x | | | | x | | | **Absolute Horizontal Accuracy** | The range of values for the error in an object's horizontal metric geolocation value with respect to a specified geodetic horizontal reference datum, expressed as a radial error at the 90 percent probability level (CE).<br>• There are two types of absolute horizontal accuracy: *predicted* absolute horizontal accuracy is based on error propagation via a statistical error model; and *measured* absolute horizontal accuracy is an empirically derived metric based on sample statistics.<br>• The term "horizontal accuracy" is assumed to correspond to "absolute horizontal accuracy".<br>• The 90% probability level (CE) is the default; 95% and 50% probability levels are optional, i.e., CE_95 and CE_50, respectively. | b,f,j |

| Technical Guidance Document (TGD) | | | | | | | | | | | | | | Term | Definition | Source/s |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 2a | | 2b | | 2c | | 2d | | 2e | | 2f | | | | |
| 3 | A | 3 | A | 3 | A | 3 | A | 3 | A | 3 | A | 3 | A | Term | Definition | Source/s |
| | x | | x | | x | | x | | | | x | | | **Absolute Vertical Accuracy** | The range of values for the error in an object's metric elevation value with respect to a vertical reference datum, expressed as a linear error at the 90 percent probability level (LE).<br>• There are two types of absolute vertical accuracy: *predicted* absolute vertical accuracy is based on error propagation via a statistical error model; and *measured* absolute vertical accuracy is an empirically derived metric based on sample statistics.<br>• The term "vertical accuracy" is assumed to correspond to "absolute vertical accuracy".<br>• The 90% probability level (LE) is the default; 95% and 50% probability levels are optional, i.e., LE_95 and LE_50, respectively. | b,f,j |
| x | | x | | x | | x | | | | x | | | | **Accuracy** | The range of values for the error in an object's metric value with respect to an accepted reference value expressed as a probability.<br>• Statements of accuracy may be developed through applications of predictive statistics or by sample statistics based on multiple independent samples of errors. | f |
| | | | | | | | | | | | | | | **Altitude** | The vertical distance of a point, or an object considered as a point, measured from a reference surface, such as mean sea level (the geoid), ellipsoid, mean terrain. | c,f |
| | x | | x | | x | | x | | | | x | | | **Bias Error** | A category of error; an error that does not vary from one realization (trial or experimental outcome) to the other. When error is represented as a random variable, random vector, stochastic process, or random field, a bias error corresponds to a non-zero mean-value.<br>• Caution: a given realization of a mean-zero stochastic process with typical temporal correlation and over a reasonable finite time interval appears to have a non-zero sample mean-value; however, when sample statistics are taken over enough multiple (independent) realizations, the sample mean-value approaches zero in accordance with the true mean-value. This characteristic extends to random fields as well. | f,j |
| | x | | x | | | | | | | | | | | **CE-LE Error Cylinder** | A 3D cylinder made up of CE and LE such that there is between 81-90% probability that the 3d error resides within. | |
| x | | x | | x | | x | | | | | x | | | **Circular Error (CE)** | See **Scalar Accuracy Metrics** | |
| | x | | x | | | | x | | | | | | | **Confidence Ellipsoid** | An ellipsoid centered at an estimate of geolocation such that there is a 90% probability (or XX% if specified specifically) that the true geolocation is within the ellipsoidal boundary (ellipsoid interior). A confidence ellipsoid is typically generated based on an error covariance matrix, an assumed mean-value of error equal to zero, and an assumed multi-variate Gaussian probability distribution of error in up to three spatial dimensions. | |

| Technical Guidance Document (TGD) | | | | | | | | | | | | | | | | |
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| | | | | | x | | x | | | | | | | **Confidence Interval** | A type of interval estimate of an unknown population parameter in statistics. More specifically, if $X$ is a vector of random samples from a probability distribution with statistical parameter $\theta$ which is to be estimated with confidence-level (confidence coefficient) $\gamma$:<br>• $prob\{a(X) < \theta < b(X)\} = \gamma$, where $a(X)$ and $b(X)$ are random end-points and functions of $X$.<br>• Note that the probability distribution need not be specified, but typically is, e.g., a Gausssian (Normal) distribution, a commonly assumed continuous probability distribution.<br>• Typical parameters represented by $\theta$ are the distribution's (or corresponding random variable's) mean-value, standard deviation, or percentile.<br>• The above confidence interval is a two-sided confidence interval; a one-sided confidence interval involves only $a(X)$ or $b(X)$ and is bounded on one side, e.g., $prob\{\theta < b(X)\} = \gamma$. | |
| | | | | | x | | x | | | | | | | **Confidence Interval (order statistics)** | Similar to a confidence interval (see above) except computed using order (nonparametric) statistics in which a specific probability distribution is not assumed and a finite set of ordered (by ascending magnitude) samples $y_i$, $i = 1,..,n$, of a random variable $x$ are available. Thus, assuming that the unknown probability distribution is continuous and that the parameter of interest is $x_p$, the $p$ percentile of the corresponding random variable $x$, as typically the case for an NSG application:<br>• $prob\{y_k < x_p < y_{k+r}\} \geq \gamma$, where the specific order sample indices $k$ and $(k+r)$ are such that $r$ is the smallest positive integer such that the probability or confidence bound is met.<br>• Note that once the order sample indices $k$ and $(k+r)$ are specified (determined), the two-sided confidence interval corresponds to a specific confidence $\gamma_0 \geq \gamma$, i.e., $prob\{y_k < x_p < y_{k+r}\} = \gamma_0$. This is the reason why $\gamma$ is sometimes referred to as the "specified (minimum) confidence-level".<br>• A one-sided confidence interval based on order statistics is typically of the form $prob\{x_p < y_{k^\wedge}\} \geq \gamma$, where the ordered sample $y_{k^\wedge}$ is the smallest valued ordered sample (equivalently, $k^\wedge$ the smallest index) such that the probability or confidence bound is met.<br>• Note that all of the above are applicable to discrete probability distributions as well; simply substitute $\leq$ for $<$ inside the interval, for example: $prob\{y_k \leq x_p \leq y_{k+r}\} \geq \gamma$. | |

| Technical Guidance Document (TGD) | | | | | | | | | | | | | | | | |
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| 1 | | 2a | | 2b | | 2c | | 2d | | 2e | | 2f | | | | |
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| | x | | x | | x | | x | | | | x | | | **Correlated Error** | A category of errors; errors that are correlated with other errors, and typically represented in the NSG as a random vector, stochastic processes, or random field. A correlated error is independent (uncorrelated) with itself and other errors from one realization (trial or experimental outcome) to the next. However, within a given realization, it is correlated with other errors of interest:<br>• If a random vector, the various elements (random variables) which make it up are correlated with each other (intra-state vector correlation).<br>• If a stochastic process, the collection of random vectors which make up the stochastic process are correlated with each other (inter-state vector correlation). That is, the elements of one random vector are correlated with the elements of another random vector, typically the closer the two random vectors in time, the greater the correlation. A similar concept is applicable to random fields. | |
| | x | | x | | x | | x | | | | x | | | **Correlated Values** | Values (of random variables) which are related by a statistical interdependence. For two random variables, this interdependence is represented by their covariance and typically expressed as a correlation coefficient – both have non-zero values. This interdependence is relative to deviations about their respective mean-values. | f |
| | x | | x | | x | | x | | | | x | | | **Covariance** | A measure of the mutual variation of two random variables, where variations (deviations or dispersions) are about their respective mean-values. If the covariance between two random values is zero, they are uncorrelated. | b |
| | x | | x | | x | | | | | | | | | **Covariance Function** | The cross-covariance matrix of two random vectors associated with a (same) stochastic process or random field as a function of their corresponding time or spatial locations, respectively. If the stochastic process is (wide sense) stationary or the random field (wide sense) homogeneous, the cross-covariance matrix is a function of delta time or delta position, respectively. When evaluated at delta equal to zero, it equals the common covariance matrix. | |
| | x | | x | | x | | x | | | | x | | | **Covariance Matrix** | A symmetric, $nxn$ positive definite matrix populated with the variances and covariances of the random variables contained within a single, multi-component ($nx1$) state vector or random vector. Note that if row $i$ ( $1 \leq i \leq n$) and all corresponding columns $j$ ( $1 \leq j \leq n$ ,$j \neq i$) are zero, random variable $i$ is uncorrelated with all of the other random variables $j$. | b |
| | x | | x | | | | x | | | | x | | | **Cross-covariance Matrix** | An $nxm$ matrix containing the covariance between each pair of elements (random variables) of an $nx1$ random vector and an $mx1$ random vector. | |

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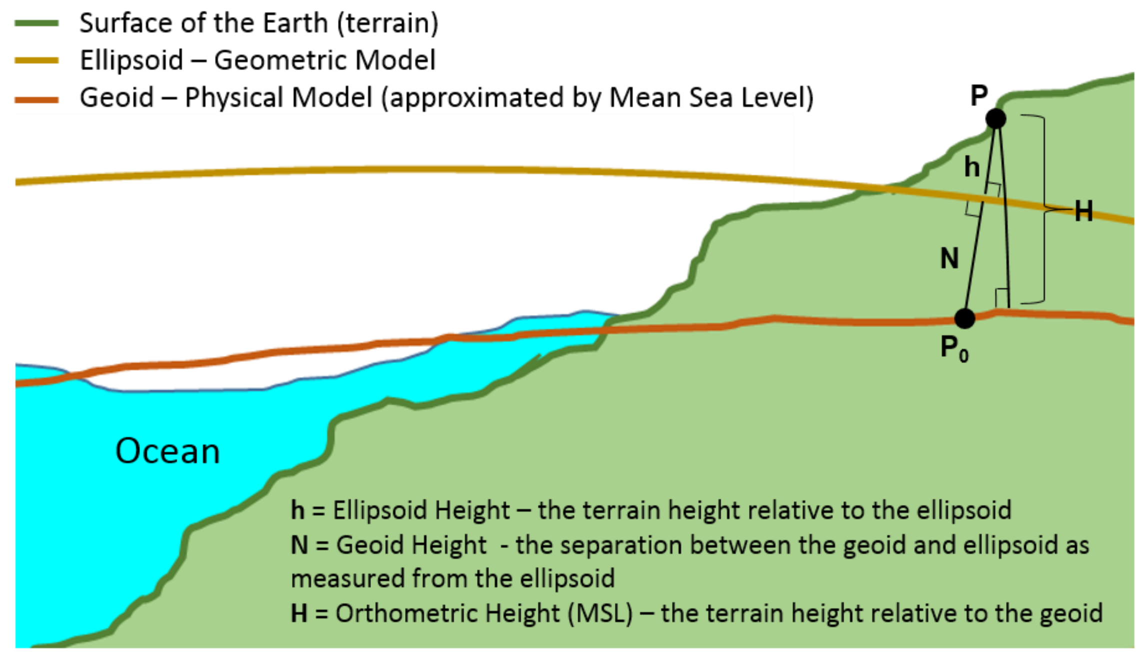
| x | | | | | | | | | | | | | | **Crowd-sourcing** | The process of obtaining data, in particular geospatial data, via individual contributions from a large group of people such as an online community, typically on a volunteered basis. | |
| | x | | x | | x | | | | | | | | | **Deterministic Error** | An error that is not random or dependent on “chance” – a “known” value, such as the specific realization of an error of an estimated geolocation as compared to “ground truth”, i.e., their difference, where “ground truth” is assumed error-free. | |
| | | | x | | | | | | | | x | | | **Distance constant** | The (separation) distance value such that the correlation coefficient for spatial correlation expressed as a decaying exponential equals $e^{-1} \cong 0.37$ . | |
| | x | | x | | x | | | | | | | | | **Earth Centered Earth Fixed Cartesian Coordinate System** | The Conventional Terrestrial Reference System (CTRS) with the following definition:<br>1) Origin: at the geocenter (center of mass of the earth).<br>2) z-axis: Directed toward the conventional definition of the North Pole, or more precise, towards the conventional terrestrial pole as defined by the International Earth Rotation Service (IERS).<br>3) x-Axis: Passes through the point of zero longitude (approximately on the Greenwich meridian) as defined by the IERS.<br>4) y-axis: forms a right-handed coordinate system with the x- and z-axes. | l |
| | x | | | | | | | | | | x | | | **Elevation** | Vertical distance above a datum, usually mean sea level, to a point or object on the Earth’s surface; not to be confused with altitude which refers to points or objects above the Earth’s surface. In geodetic formulas, elevations are heights: $h$ is the height above the ellipsoid; $H$ is the height above the geoid or local datum. Occasionally $h$ and $H$ may be reversed. See definition of **Height** for further information. | c,f |
| x | | x | | x | | x | | | | x | | | | **Error** | The difference between the observed or estimated value and its ideal or true value. See Appendix A for a more detailed and augmented definition. | f |

| Technical Guidance Document (TGD) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 2a | | 2b | | 2c | | 2d | | 2e | | 2f | | | | |
| 3 | A | 3 | A | 3 | A | 3 | A | 3 | A | 3 | A | 3 | A | Term | Definition | Source/s |
| | x | | x | | x | | x | | | | x | | | **Error (augmented definition)** | The difference between the observed or estimated value and its ideal or true value. [e] There are a number of different categories of errors applicable to the NSG: Bias Error, Random Error, and Correlated Error. In general, an error of interest may be a combination of errors from these categories. Their combination is typically represented as either a random variable, random vector, stochastic process, or random field:<br>• A random variable represents a bias error plus a random error. The former corresponds to the random variable's mean-value, and if equal to zero, the random variable represents random error only, which is uncorrelated from one realization of the random variable to the next realization.<br>• A random vector, stochastic process, and random field can represent all three categories of error. The random variables that make-up (are elements of) random vectors are uncorrelated from one realization to the next by definition. However, within a given realization, they can also be correlated with each other:<br>○ For a random vector per se, this correlation is also termed "intra-state vector correlation".<br>○ For a stochastic process, which consists of a collection of random vectors, random variables in one random vector can also be correlated with random variables in another random vector; this is also termed "inter-state vector" correlation. The same concept is applicable to random fields. | f |
| | x | | x | | x | | x | | | | x | | | **Error Ellipsoid** | An ellipsoid such that there is a 90% probability (or XX% if specified specifically) that geolocation error is within the ellipsoidal boundary (ellipsoid interior). An error ellipsoid can be generated based on a predictive or sample-based error covariance matrix, centered at an assumed predictive mean-value of error equal to zero or a sample-based mean-value of error not equal to zero, and an assumed multi-variate Gaussian probability distribution of error in up to three dimensions. | |

| Technical Guidance Document (TGD) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 2a | | 2b | | 2c | | 2d | | 2e | | 2f | | | | |
| 3 | A | 3 | A | 3 | A | 3 | A | 3 | A | 3 | A | 3 | A | Term | Definition | Source/s |
| | x | | x | | | | x | | | | x | | | **Estimator** | An algorithm/process which estimates the value of an nx1 state vector. Its inputs are measurements related to the state vector and may include *a priori* information about the state vector.<br>• An estimator is usually designed to be an optimal estimator relative to a cost function, such as the sum of weighted *a posteriori* measurement residuals, minimum mean-square solution error, etc.<br>• Estimators are sequential or batch processes, and an optimal estimator should include both an estimate of the state vector and its predicted accuracy, usually an error covariance matrix, as output. A properly implemented MIG for a target's geolocation is an optimal estimator. | |
| x | | | | | | | | | | | | | | **External Data** | In the context of this document, external data is geospatial data that is obtained by purchase or openly available public sources. Outsourced data and crowd-sourced data are examples of external data. | |
| x | | x | | | | | | | | | x | | | **Fusion** | A process that combines or relates different sources of (typically independent) information. | |
| | x | | x | | x | | x | | | | x | | | **Gaussian (or Normal) probability distribution** | A specific type of probability distribution for a random variable. The distribution is specified by either a Gaussian probability density function or a Gaussian cumulative distribution function. These in turn are completely characterized by the random variable's mean-value and variance.<br>• The Gaussian (probability) distribution is a common distribution that approximates many kinds of errors of interest to the NSG, and approximates the distribution for a sum of errors from different (non-Gaussian) distributions as well (Central Limit Theorem). A Gaussian distribution corresponding to an nx1 random vector is termed a multi-variate Gaussian distribution. | |
| | x | | x | | x | | | | | | | | | **Geodetic Coordinate System** | Coordinate system in which position is specified by geodetic latitude, geodetic longitude and (in the three-dimensional case) ellipsoidal height. | d |
| | x | | x | | x | x | | | | | | | | **Ground Truth** | The reference or (assumed) true value of a geolocation of a measured quantity (e.g. associated with an absolute geolocation, or a relative mensuration). | |

<table>
<tr><th colspan="14">Technical Guidance Document (TGD)</th><th rowspan="3">Term</th><th rowspan="3">Definition</th><th rowspan="3">Source/s</th></tr>
<tr><th colspan="2">1</th><th colspan="2">2a</th><th colspan="2">2b</th><th colspan="2">2c</th><th colspan="2">2d</th><th colspan="2">2e</th><th colspan="2">2f</th></tr>
<tr><th>3</th><th>A</th><th>3</th><th>A</th><th>3</th><th>A</th><th>3</th><th>A</th><th>3</th><th>A</th><th>3</th><th>A</th><th>3</th><th>A</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>Height</td><td>The vertical distance of an object, point, or level above the ground or other established reference surface. The figure below depicts some specific height measurements common in the NSG.




*Note: Height is defined as measured above a reference surface h, N, and H can positive or negative values. In this diagram, h and H would have positive values and N would have a negative value.

For further information on the terms in this image consider the following resources:<br>http://earth-info.nga.mil/GandG/publications/vertdatum.html,<br>http://earth-info.nga.mil/GandG/coordsys/definitions.html<br>and for a deeper treatment of the topic, DMA Technical Report: Geodesy for the Layman (1983) is available here: http://earth-info.nga.mil/GandG/publications/geolay/toc.html,<br>or in pdf here: http://earth-info.nga.mil/GandG/publications/geolay/Geo4lay.pdf</td><td>c,f</td></tr>
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| Technical Guidance Document (TGD) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 2a | | 2b | | 2c | | 2d | | 2e | | 2f | | | | |
| 3 | A | 3 | A | 3 | A | 3 | A | 3 | A | 3 | A | 3 | A | Term | Definition | Source/s |
| | x | | x | | | | | | | | x | | | **Homogeneous** | A descriptor for a random field. A random field is (wide-sense) homogeneous if corresponding (*a priori*) statistics are invariant to spatial location. For example, the mean-value and covariance matrix corresponding to its random vectors are constant, and correlation between two corresponding but arbitrary random vectors in the same realization is a function of spatial distance between them, not the explicit spatial location of each. | |
| | x | | x | | x | | x | | x | | x | | x | **Horizontal Error** | As applied to geospatial measurements and processes, horizontal error is typically observed in the $x, y$ plane of a local right-handed coordinate system where the $x, y$ plane is defined as tangent to the defined reference surface at the point of origin. While horizontal error is the $x$ and $y$ components of error, it may be generalized by its magnitude or 2D radial error. | |
| | x | | x | | x | | x | | | | x | | | **Inter-state vector correlation** | The correlation between the errors (random variables) of the elements in two different state vectors. | |
| | x | | x | | x | | x | | | | x | | | **Intra-state vector correlation** | The correlation between the errors (random variables) of different elements in the same state vector. | |
| | | | | | x | | x | | | | | | | **Least-upper-bound (lub)** | The smallest value (real number) greater than or equal to a quantity of interest, assuming an analytic (deterministic) application. If a statistical or probabilistic-based application, the definition is extended to account for random variables. In particular, for the specification and validation of accuracy based on order statistics using i.i.d. samples of the random variable defined as geolocation radial error, and assuming that horizontal radial error at the 50th percentile is of interest for specificity:<br><br>• The least-upper-bound $lub\_\epsilon h_{50}$ is defined as the smallest value greater than the true (and unknown) 50th percentile of horizontal radial error $\epsilon h_{50}$, where horizontal radial error $\epsilon h$ is a random variable. The least-upper-bound also corresponds to an accompanying and independently specified (minimum) level-of-confidence, typically 90%. Correspondingly, $lub\_\epsilon h_{50}$ is equal to the smallest order sample value of horizontal radial error such that:<br>    ○ $prob\{\epsilon h_{50} < lub\_\epsilon h_{50}\} \geq 0.90$<br>• As the number of samples increase, the closer (statistically) $lub\_\epsilon h_{50}$ comes to $\epsilon h_{50}$.<br>• The (probabilistic) lub is equivalent to a one-sided confidence interval based on order statistics. | |
| x | | x | | x | | x | | | | | x | | | **Linear Error (LE)** | See **Scalar Accuracy Metrics** | |

| Technical Guidance Document (TGD) | | | | | | | | | | | | | | | | |
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| | x | | x | | x | | x | | | | x | | | **Local Tangent Plane Coordinate System (Coordinate System/Coordinate Reference System)** | A local X,Y,Z right-handed rectangular coordinate system such that the origin is any point selected on a given reference ellipsoid, its XY plane is tangent to the reference ellipsoid at the point of origin, and the Y-axis is typically directed to the North Pole (an East-North-Up (ENU) system). | a |
| | x | | x | | x | | x | | | | x | | | **Mean-Value** | The expected value of a random variable. Given a collected sample of measurements, the sample mean-value is the average of the values of the sample measurements. The mean-value of a predictive error is typically assumed zero unless specifically stated otherwise. If correctly modelled, the predictive mean-value should be closely approximated by the sample mean-value taken over a large number of independent and identically distributed samples.<br>• The concept of mean-value readily extends to random vectors and is the vector of the mean-values of the individual components or random variables making up the random vector. It readily extends to stochastic processes and random fields as well, since they are collections of random vectors. If (wide-sense) stationary or (wide-sense) homogeneous, respectively, their corresponding mean-value is a constant random vector mean-value. | |
| | x | | x | | | | | | | | x | | | **Metadata** | Higher level or ancillary data describing a collection of data, e.g., the sensor support data corresponding to an image, which specifies corresponding sensor position, attitude, interior orientation parameters, etc. | |
| x | | x | | | | x | | | | x | | | | **Monte-Carlo Simulation** | A technique in which a large number of independent sample inputs for a system are randomly generated using an assumed *a priori* statistical model to analyze corresponding system output samples statistically and support derivation of a statistical model of the system output. This technique is valuable for complex systems, non-linear systems, and those where no insight to internal algorithms is provided ("black box" systems). | |
| | x | | x | | | | x | | | | x | | | **Multi-Image Geopositioning (MIG)** | An optimal solution for a "target's" geolocation (state vector) with reliable predicted accuracies based on the (weighted) measurements of the geolocation in one or more images. A batch process which minimizes the sum of weighted *a posteriori* measurement residuals, where the latter may also include measurements equivalent to *a priori* estimates of geolocation. MIG can also correspond to the simultaneous solution for the geolocation of multiple targets. In general, a MIG solution's predicted accuracies correspond to or are derived from the solution's *a posteriori* error covariance matrix. | |

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| 3 | A | 3 | A | 3 | A | 3 | A | 3 | A | 3 | A | 3 | A | | | |
| | x | | x | | | | | | | | | | | **Multi-State Vector Error Covariance Matrix** | An error covariance matrix corresponding to multiple state vector errors (random error vectors) "stacked" one on top of the other as one large state vector error (random error vector), e.g. to represent the position and attitude errors of multiple images' adjustable parameter errors that impact the solution and predicted accuracy of a subsequent MIG. The multi-state vector error covariance matrix is sometimes termed the joint covariance matrix for a collection of multiple state vector errors. | |
| x | | x | | x | | x | | | | x | | | | **National System for Geospatial Intelligence (NSG)** | The operating framework supported by producers, consumers or influencers of geospatial intelligence (GEOINT). Spanning defense, intelligence, civil, commercial, academic and international sectors, the NSG contributes to the overall advancement of the GEOINT function within the strategic priorities identified by the Functional Manager for Geospatial Intelligence in the role established by Executive Order 12333. The framework facilitates community strategy, policy, governance, standards and requirements to ensure responsive, integrated national security capabilities. | i |
| | x | | x | | x | | x | | | | x | | | **Order Statistics** | Nonparametric statistics performed on a set ordered by ascending magnitude of randomly sampled values. Nonparametric statistics assume no *a priori* information about the underlying probability distribution of a random variable such as its mean-value, variance, or type of probability distribution function. In the NSG, order statistics are used to compute scalar accuracy metrics from independent and identically distributed samples of error. | |
| x | | | | | | | | | | | | | | **Outsourced data** | Data obtained through purchase (contract) which may be contingent on specified collection or production criteria. | |
| | x | | x | | x | | x | | | | x | | | **Percentile** | If a random variable's probability (or sample) distribution is divided into 100 equal parts, the value of the random variable that corresponds to the percentage of the distribution equal to or below the specified percentile, e.g. the 90$^{th}$ percentile indicates the lowest sample value such that it is greater than the values of 90 percent of the samples.<br>• A more formal definition is as follows: The $p$ percentile of a random variable $x$ is defined as the smallest number $x_p$ such that $p = prob\{x \le x_p\}$. Thus, the probability distribution function (typically unknown) of the random variable $x$ evaluated at $x_p$ is equal to $p$. $x_p$ is a deterministic parameter with typically unknown value. | |
| | x | | x | | x | | x | | | | | | | **Precision** | The closeness to one another of a set of repeated observations of a random variable.<br>• In terms of accuracy, precision is a measure of the repeatability of the underlying errors. High accuracy implies high precision, but not vice versa. For example, for an error represented as a random variable, high precision implies a small standard deviation, but high accuracy implies both a small standard deviation and a small or zero mean-value (or bias). | a,f |

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| x | | x | | x | | x | | | | x | | | | **Predicted Accuracy** | The range of values for the error in a specific object's metric value expressed as a probability derived from an underlying and accompanying detailed statistical error model.<br>• If the statistical error model does not include the identification of a specific probability distribution, a Gaussian (or Normal) probability distribution is typically assumed in order to generate probabilities.<br>• The term "Predicted" in Predicted Accuracy corresponds to the use of predictive statistics in the detailed statistical error model; it does not correspond to a prediction of accuracy applicable to the future since the corresponding error corresponds to a geolocation already extracted. | |
| x | | x | | x | | x | | | | x | | | | **Predictive Statistics** | Statistics corresponding to the mathematical modeling of assumed *a pri*ori error characteristics contained in a statistical error model. | |
| | x | | x | | x | | | | | | x | | | **Principal Matrix Square Root** | The principal matrix square root of a valid error covariance matrix is a valid error covariance matrix itself of the same dimension such that when multiplied with itself yields the original error covariance matrix. The calculation of principal matrix square root is based on Singular Value Decomposition. | |
| | x | | x | | x | | x | | | | x | | | **Probability density function (pdf)** | A function that defines the probability distribution of a random variable. If continuous, its integral is the (cumulative) probability distribution function. | |
| | x | | x | | x | | x | | | | x | | | **Probability distribution** | Identifies the probability of a random variable's values over an applicable range of values. There are many different types of probability distributions: Gaussian or Normal, uniform, exponential, etc.<br>• In most NSG applications for accuracy and predicted accuracy, the random variable and its probability distributions are assumed continuous.<br>• The probability distribution is specified by either a probability density function or a (cumulative) probability distribution function; either based on an a *priori* model or sample statistics. | |
| | x | | x | | x | | x | | | | | | | **Probability distribution function (cdf)** | The (cumulative) probability distribution function defines the probability that a random variable's value is less than or equal to a specified number in the interval [0,1]. | |
| | x | | | | | | | | | | | | | **Provenance** | The place of origin or generation history of data. | |
| x | | x | | | | | | | | | | | | **Quality Assurance** | The maintenance of a desired level of quality in a service or product, especially by means of attention to every stage of the process of delivery or production. | k |

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| x | | x | | | | | | | | | | | | **Quality Assessment** | Processes and procedures intended to verify the reliability of provided data and processes, typically performed independent of collection or production. For example, If ground truth is available, then comparison of actual (sample) errors to predicted errors (statistical values via rigorous error propagation) is a key part of this process. | |
| | x | | x | | x | | x | | x | | x | | x | **Radial Error** | A generalization of two horizontal error components $(x, y)$ or three dimensional (horizontal and vertical error components – $x, y, z$) error components to a distance value (magnitude) as measured along the radius of a circle or sphere, respectively. | |
| | x | | x | | x | | x | | | | x | | | **Random Error** | A category of error; a measure of deviation from an ideal or true value which results from an accidental and unknown combination of causes and varies from one measurement to the next. Not deterministic. For NSG applications, a random error is typically represented as a random variable, random vector, stationary process, or random field. And more specifically, as deviations about their mean-values, the latter considered biases.<br>• The random error corresponding to a random variable or the random error corresponding to (the elements of) a random vector are independent (uncorrelated) from one realization to the next, by definition.<br>• The random error corresponding to (the elements of) a random vector can also be correlated between the various elements for a given realization (intra-state vector correlation); hence this error is also a correlated error.<br>• The random error corresponding to a stochastic process corresponds to the collection of random errors associated with the collection of random vectors making up the stochastic process. Random error is independent (uncorrelated) from one realization to the next. However, within a specific realization, the individual random error vectors are typically temporally correlated amongst themselves (inter-state vector correlation); hence, random error is also correlated error. This same characteristic extends to random fields.<br>• The probability distribution for a random variable representing a random error is arbitrary – not necessarily Gaussian. | b,f |
| | | | x | | | | x | | | | x | | | **Random Error Vector** | An error represented by a nx1 random vector, and in the NSG, typically corresponds to the error in a state vector's value. The error itself could correspond to a combination of errors from different error categories: bias error, random error, and/or correlated error. That is, the term "random error vector" does not imply the corresponding category of error is necessarily (only) "random error". | |

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| | x | | x | | x | | | | | | x | | | **Random Field** | A random field (RF) is a collection of random vectors (RV), parameterized by an N-dimensional spatial vector q. In general, two different random vectors from the same realization of the random field are correlated. In the NSG, when error is represented by a random field, its corresponding statistics are specified by a statistical error model. A general descriptor of a given random field is as follows: a ("scalar" or "multi-variate") ("homogeneous" or "non-homogeneous") "ND random field".<br>• Scalar (n=1) or multi-variate (n>1) refers to the number of elements n that each random vector contains and is sometimes described as "(nd)", e.g. (2d) corresponds to 2 elements (random variables) per random vector.<br>• Homogeneous or non-homogeneous refers to whether the corresponding statistics are invariant or vary over spatial location q.<br>• ND refers to the number of spatial dimensions (number of elements in q), e.g. 3D corresponds to 3 spatial dimensions. Each random vector corresponds to a unique value of q.<br>• As an example of terminology, "a multi-variate homogeneous 3D random field" or more specifically "a homogeneous 3D random field (2d)" corresponds to a multi-variate homogeneous random field over 3 spatial dimensions (q is a vector with 3 elements). The random vectors contain 2 elements.<br>• Spatial dimensions are general. For typical NSG applications, they correspond to some combination of geolocation directions and time. Note that a stochastic process is also a random field with N=1.<br>• In general, the collection of random vectors is infinite for a random field; however, only a finite subset are of interest for most applications, i.e., random vectors associated with a finite set of spatial locations.<br>• For typical NSG applications, the spatial correlation of a random field is specified by one of more strictly positive definite correlation functions (spdcf) contained in the corresponding statistical error model. | |

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| | x | | x | | x | | x | | | | x | | | **Random Variable** | A variable whose value varies by chance, i.e., non-deterministic. Somewhat more formally, a random variable is a mapping from the space of experimental outcomes to a space of numbers. In the NSG, when error is represented by a random variable (a random vector with one component or element, i.e., n=1), its corresponding statistics are specified by a statistical error model.<br>• For most NSG applications, the space of experimental outcomes is already a number. For example, the x-component of sensor position can be considered a random variable. Equivalently, it can be defined as the true x-component of sensor position plus x-component of sensor position error, the former a deterministic (typically unknown) value and the latter a random variable.<br>• A random variable is statistically characterized by its mean-value, variance, and (more completely) its probability density function (pdf). The probability density function (pdf) is typically unknown and not included, but if needed for the calculation of probabilities, assumed Gaussian distributed with the pdf completely characterized by the mean-value and variance. | |
| | x | | x | | x | | x | | | | x | | | **Random Vector** | A random vector (RV) is an nx1 vector which contains n random variables as components or elements. In the NSG, when error is represented as a random vector, its corresponding statistics are specified by a statistical error model. The corresponding random vector is also sometimes termed a random error vector.<br>• The realization of a Random Vector corresponds to a specific value of the vector (components or elements) for a given event such as a trial or experiment. Important descriptive statistics of a RV are its mean (vector) value and the error covariance matrix about the mean, and optionally, a multi-variate probability density function. These statistics can be predictive or sample-based. | |
| | x | | x | | x | | x | | | | x | | | **Realization** | For NSG accuracy and predicted accuracy applications, a specific trial or experimental outcome or independent sample involving a random error (category of error). | |
| | x | | x | | x | | x | | | | | | | **Relative Horizontal Accuracy** | The range of values for the error in the difference between two objects' horizontal metric geolocation values with respect to a specified geodetic horizontal reference datum; e.g. expressed as a radial error at the 90 percent probability level (CE90). There are two types of relative horizontal accuracy: predicted relative horizontal accuracy is based on error propagation via a statistical error model(s); and measured relative horizontal accuracy is an empirically derived metric based on sample statistics. | |

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| | x | | x | | x | | x | | | | | | | **Relative Vertical Accuracy** | The range of values for the error in the difference between two objects' vertical metric geolocation values with respect to a specified geodetic vertical reference datum; e.g. expressed as a linear error at the 90 percent probability level (LE90). There are two types of relative vertical accuracy: predicted relative vertical accuracy is based on error propagation via a statistical error model(s); and measured relative vertical accuracy is an empirically derived metric based on sample statistics. | |
| | x | | | | | | x | | | | x | | | **Rigorous Error Propagation** | Represents the proper statistical modeling of all significant errors and their interrelationships throughout an NSG system. It enables optimal solutions as well as reliable predicted accuracies associated with specific estimates and products across the system modules. | |
| x | | x | | x | | x | | | | x | | | | **Sample Statistics** | Statistics corresponding to the analysis of a collection of physical observations, a sample of the population, as compared to an assumed true or an *a priori* value. | |
| x | | x | | x | | x | | | | x | | | | **Scalar Accuracy Metrics** | Convenient one-number summaries of geolocation accuracy and geolocation predicted accuracy expressed as a probability: (1) Linear Error (LE) corresponds to 90% probable vertical error, (2) Circular Error (CE) correspond to 90% probable horizontal radial error, and (3) Spherical Error (SE) corresponds to 90% spherical radial error. See Appendix A for a more detailed and augmented definition. | b,f,h |

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| | x | | x | | x | | x | | | | x | | | **Scalar Accuracy Metrics (augmented definition)** | Convenient one-number summaries of geolocation accuracy and geolocation predicted accuracy expressed as a probability:<br>• Linear Error (LE) - LE is an unsigned value that corresponds to the length of a vertical line (segment) such that there is a 90% probability that the absolute value of vertical error resides along the line. If the line is doubled in length and centered at the target solution, there is a 90% probability that the true target vertical location resides along the line. LE_XX corresponds to LE at the XX % probability level.<br>• Circular Error (CE) - CE is an unsigned value that corresponds to the radius of a circle such that there is a 90% probability that the horizontal error resides within the circle; or equivalently, if the circle is centered at the target solution, there is a 90% probability the true target horizontal location resides within the circle. CE_XX corresponds to CE at the XX % probability level.<br>• Spherical Error (SE) - SE is an unsigned value that corresponds to the radius of a sphere such that there is a 90% probability that 3d error resides within, or equivalently, if the sphere is centered at the target solution, there is a 90% probability that the true target location resides within the sphere. SE_XX corresponds to SE at the XX % probability level.<br>For the above scalar accuracy metrics:<br>• It is assumed that the underlying $x$-$y$-$z$ coordinate system is a local tangent plane system, i.e., $x$ and $y$ are horizontal components and $z$ the vertical component.<br>• CE-LE corresponds to the CE-LE error cylinder. There is a probability between 81 to 90 percent that 3d radial error resides within the cylinder. The former value corresponds to uncorrelated horizontal and vertical errors, the latter value to highly correlated horizontal and vertical errors.<br>• LE_XX, CE_XX, and SE_XX (aka LEXX, CEXX, and SEXX, respectively) are also called XX percentiles for absolute vertical errors, horizontal radial errors, and spherical radial errors, respectively. XX is expressed as an integer greater than zero and less than 100. | b,f,h |
| | x | | x | | | | | | | | x | | | **Sensor support data** | See **Metadata** | |
| | x | | x | | x | | | | | | x | | | **Spatial Correlation** | The correlation between the elements (random variables) of two random vectors at two different spatial locations associated with the same realization of a random field. | |
| x | | x | | x | | | | | | | | | | **Spherical Error (SE)** | See **Scalar Accuracy Metrics** | |

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| | x | | x | | x | | x | | | | x | | | **Standard Deviation** | The square root of the variance of a random variable. A measure of deviation or dispersion about the random variable's mean-value. | |
| | x | | x | | | | x | | | | x | | | **State Vector** | A vector of parameters or variables that describe a system's state. | |
| | x | | x | | | | x | | | | x | | | **State Vector Error** | A vector of errors corresponding to an estimate of a state vector relative to a (typically unknown) true state vector; a random vector of errors, or random error vector. | |
| | x | | x | | | | | | | | x | | | **Stationary** | A descriptor for a stochastic process with corresponding (*a priori*) statistics invariant over time. See homogeneous as well for random fields, which if corresponding to one spatial dimension are stochastic processes. | |
| x | | x | | x | | x | | | | x | | | | **Statistical Error Model** | Information which describes the error data corresponding to a given state vector. The information includes the type of corresponding error representation (random variable, random vector, stochastic process, or random process), the category of statistics (predictive or sample), and associated statistical information including at a minimum the mean-value and covariance data. | |
| | x | | x | | x | | | | | | x | | | **Stochastic Process** | A stochastic process (SP) is a collection of random vectors (RV), parameterized by a 1D quantity, typically time. For a given realization of the stochastic process, the individual random vectors are correlated with each other. If the random vectors consist of one element or component (n=1), the stochastic process is sometimes called a scalar stochastic process, and if greater than one, a multi-variate stochastic process. A stochastic process is also a random field with one spatial (or time) dimension, i.e., N=1. In the NSG, when error is represented as a stochastic process, its corresponding statistics are specified by a statistical error model. | |
| | x | | x | | x | | | | | | x | | | **Strictly Positive Definite Correlation Function (spdcf)** | A function which models the statistical correlation between random vectors (random variables), typically applied in the NSG to describe the temporal correlation and/or spatial correlation between various random vectors which are part of a stochastic process or random field, i.e., the spdcf is a function of delta time or delta distance (possibly in each of multiple directions) between random vectors. The proper use of an spdcf ensures assembly of a valid multi-state vector error covariance matrix, i.e., positive definite and symmetric. | |

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| | x | | x | | x | | | | | | | | | **Systematic Error** | An error characteristic or error effect due to errors that are represented by random variables, random vectors, stochastic processes, or random fields. For example, an effect on observations (samples) such that their pattern of magnitude and direction are consistent but not necessarily constant. Such an effect can be associated with:<br>• Error(s) represented by a stochastic process or random field which appear systematic across time or space, respectively, due to temporal or spatial correlation, respectively.<br>• The error in a frame image-to-ground sensor model's adjustable parameter for focal length. This error is typically represented by a random variable, with a mean-value of zero and a constant variance, but its effect when projected to the ground appears as a systematic error across ground locations, e.g., it has a scaling effect which increases the closer the ground point to the image footprint's boundary. | f,j |
| | x | | x | | x | | | | | | x | | | **Temporal Correlation** | The correlation between the elements (random variables) of two random vectors at two different times associated with the same realization of a stochastic process. | |
| | x | | x | | | | | | | | x | | | **Time Constant** | The delta time value such that the correlation coefficient for temporal correlation expressed as a decaying exponential equals $e^{-1} \cong 0.37$. | |
| | x | | x | | | | x | | | | | | | **Uncertainty** | A lack of certainty; limited knowledge; unknown or imperfect information. In terms of NSG applications, more general than the concepts of errors and accuracy, but sometimes used informally as a synonym. Applies to predicted accuracy but not to empirical (sample-based) accuracy. | |
| | x | | x | | x | | x | | | | x | | | **Uncorrelated Error** | At an intuitive level, an error that is statically unrelated to all other relevant errors. More precisely, if two random variables represent two uncorrelated errors (about their respective mean-values), their covariance and their corresponding correlation coefficient are zero. A random variable is uncorrelated (with itself) from one realization to the next by definition. This latter property is also true for the random variables making up random vectors, stochastic processes, and random fields. However, these three representations typically include correlated errors within the same realization. | |
| | x | | x | | x | | x | | | | x | | | **Uncorrelated Values** | Values (of random variables or errors) which are statistically unrelated. This is represented for two random variables by their covariance with a value of zero. | f |
| x | | x | | x | | x | | | | | | | | **Validation** | The process of determining the degree to which a model is an accurate representation of the real world from the perspective of its intended use/s. In the NSG, this includes validation of accuracy and predicted accuracy specified capabilities. | e |

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| x | | x | | x | | | x | | | | x | | | **Variance** | The measure of the dispersion of a random variable about its mean-value, also the standard deviation squared. | b |
| x | | | | | | | | | | | | | | **Verification** | The process of determining that an implemented model accurately represents the developer's conceptual description and specifications. | e |
| | x | | x | | x | | x | | x | | x | | | **Vertical Error** | As applied to geospatial measurements and processes, vertical error is a signed and one dimensional (linear) error value typically observed in the direction of the $z$-axis of a local right-handed coordinate system where the $x, y$ plane is defined as tangent to the defined reference surface at the point of origin and the $z$-axis is normal to the $x, y$ plane and positive in the up direction. | |
| | x | | x | | x | | | | | | | | | **WGS-84 - World Geodetic System 1984** | A documented and formally maintained global coordinate system which allows an unambiguous representation of positional information by providing the basic reference frame (coordinate system), geometric figure for the earth (ellipsoid), earth gravitational model, and means to relate positions on various geodetic datum and systems for DoD operations and applications. | g |

# 4 Notes

## 4.1 Intended Use

This information and guidance document provides technical guidance to inform the development of geospatial data accuracy characterization for NSG GEOINT collectors, producers and consumers -- accuracy characterization as required to describe the trustworthiness of geolocations for defense and intelligence use and to support practices that acquire, generate, process, exploit, and provide geolocation data and information based on geolocation data. This Glossary of Terms supports a series of complementary documents. TGD 1 provides an overview to more detailed topical technical guidance provided in TGD 2a – TGD 2f on the subjects of predictive Statistics sample statistics, specification and validation, estimators and quality control, Monte-Carlo simulation, and external data and quality assessment.

# 5 References

There are a number of authoritative guides as well as existing standards within the NSG and Department of Defense for definitions of the terms used in this series of technical guidance document and collected in this glossary. In many cases, the existing definitions provided by these sources are either too general or, in some cases, too narrow or dated by intended purposes contemporary to the document's development and publication. The definitions provided in this document have been expanded and refined to explicitly address details relevant to the current and desired future use of accuracy in the NSG. To acknowledge the basis and/or linage of certain terms, the following sources are considered as either foundational or contributory:

[a] Anderson, James M. and Mikhail, E., Surveying: Theory and Practice, 7th Edition, WCB/McGraw-Hill, 1998.

[b] DMA-TR-8400.1, DMA Technical Report: Error Theory as Applied to Mapping, Charting, and Geodesy.

[c] Defense Mapping Agency, Glossary of Mapping, Charting, and Geodetic Terms, 4th Edition, Defense Mapping Agency Hydrographic/Topographic Center, 1981.

[d] ISO TC/211 211n2047, Text for ISO 19111 Geographic Information - Spatial referencing by coordinates, as sent to the ISO Central Secretariat for issuing as FDIS, July 17, 2006.

[e] Joint Publication (JP) 1-02, Department of Defense Dictionary of Military and Associated Terms, November 8, 2010 as amended through January 15, 2016.

[f] MIL-HDBK-850, Military Handbook: Glossary of Mapping, Charting, and Geodetic Terms, January 21, 1994.

[g] MIL-STD-2401, Department of Defense Standard Practice; Department of Defense World Geodetic System (WGS), January 11, 1994

[h] MIL-STD-600001, Department of Defense Standard Practice; Mapping, Charting and Geodesy Accuracy, February 26, 1990.

[i] *National System for Geospatial Intelligence* [Brochure] Public Release Case #15-489.

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